Bellcomm

955 L'Enfant Plaza North, S.W.
Washington, D. C. 20024

B71 12007

date: December 6, 1971

to: Distribution

from: K. P. Klaasen

subject: Real-Time Determination of PLSS $O_2$ Walkback Constraints During Lunar Surface Traverses -- Case 310

## ABSTRACT

PLSS $O_2$ is the limiting consumable for Apollo 16 lunar surface traverse distance and EVA duration. Pre-mission planning can keep the nominal traverses within the maximum return distance to the LM for which sufficient $O_2$ remains to walk back from a failed LRV. However, a method of keeping the actual traverses within this constraint during the mission is required to take into account variations between the planned and actual values for metabolic rates, initial PLSS charge, and $O_2$ leak rates. A series of boundary curves has been derived that can be laid over the real-time plot of $O_2$ quantity remaining versus EVA time to indicate the emergency walkback constraint. Using the actual $O_2$ usage rates and predicted time of $O_2$ depletion, the required departure time from any station can be easily determined. These boundary curves could be used by the TELMU team in Mission Control to inform the Experiment Officer of the stations that are time-limited by the $O_2$ walkback constraint well enough in advance to allow adequate real-time traverse planning.

(NASA-CR-125365) REAL-TIME DETERMINATION OF PLSS O2 WALKBACK CONSTRAINTS DURING LUNAR SURFACE TRAVERSES (Bellcomm, Inc.) 12 p

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MEMORANDUM FOR FILE

An analysis of the Apollo 16 lunar surface traverses shows the PLSS $O_2$ to be the limiting consumable on traverse distance and EVA duration. Figures 1-3 show the traverses plotted within their constraint envelopes for the three lunar surface EVA's. The traverses and traverse planning assumptions are those presented at the November 15, 1971 Science Working Panel Meeting. At both Station 8 on EVA 2 and Station 14 on EVA 3, the $O_2$ walkback limit is closely approached. Pre-mission planning can keep the nominal traverses within this $O_2$ constraint; however, such planning does not guarantee that the traverses as actually performed will remain within the constraint boundary. In fact, the $O_2$ boundary will shift for the actual traverses due to variations between the planned and actual values for metabolic rates, initial PLSS charge, and $O_2$ leak rates. Therefore, the $O_2$ walkback constraint as plotted in Figures 1-3 is of little use in real time. Some other method must be used during the Apollo 16 mission to insure that this constraint is not violated, and this method must take into account the effects of variations in metabolic rates, initial PLSS charge, and $O_2$ leak rates.

The $O_2$ walkback limit represents the maximum distance the crew can be from the LM at any given time during the EVA and still have enough $O_2$ remaining to be able to walk back to the LM from a failed LRV, ingress, and connect to the LM $O_2$ supply. The assumed walkback speed is 3.6 km/hr over uncorrected map distance for total return times of up to 1 hour and 2.7 km/hr for longer returns. The metabolic rates involved in an emergency walkback are assumed to be 1560 BTU/hr at 3.6 km/hr and 1290 BTU/hr at 2.7 km/hr. The PLSS $O_2$ must be sufficient to cover the walkback as well as 10 min of activity at the LRV to troubleshoot and/or gather equipment together and 13 min for LM ingress. The metabolic rate associated with this additional

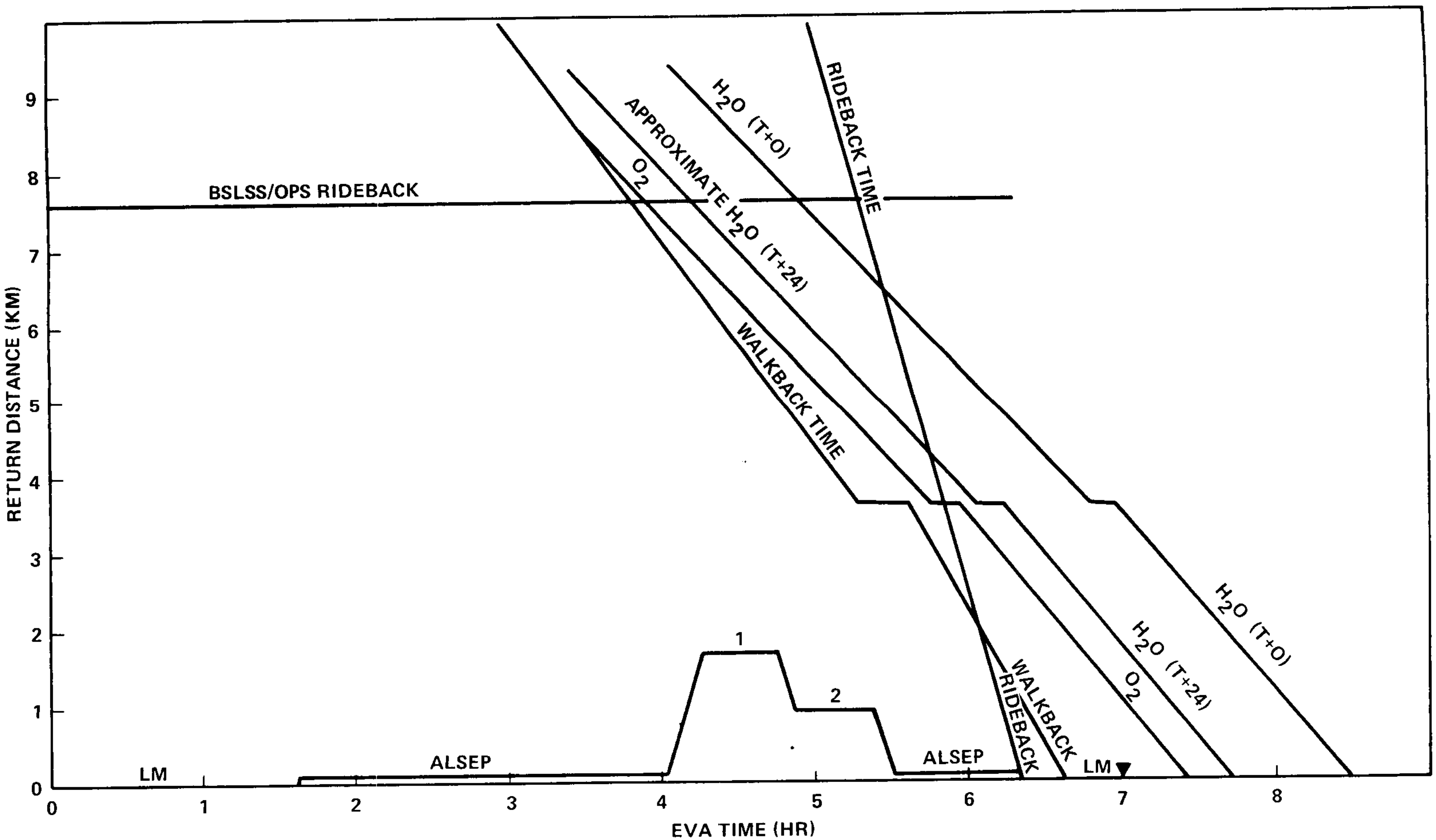


FIGURE 1 - APOLLO 16 LRV TRAVERSE CONSTRAINT ENVELOPE, EVA 1

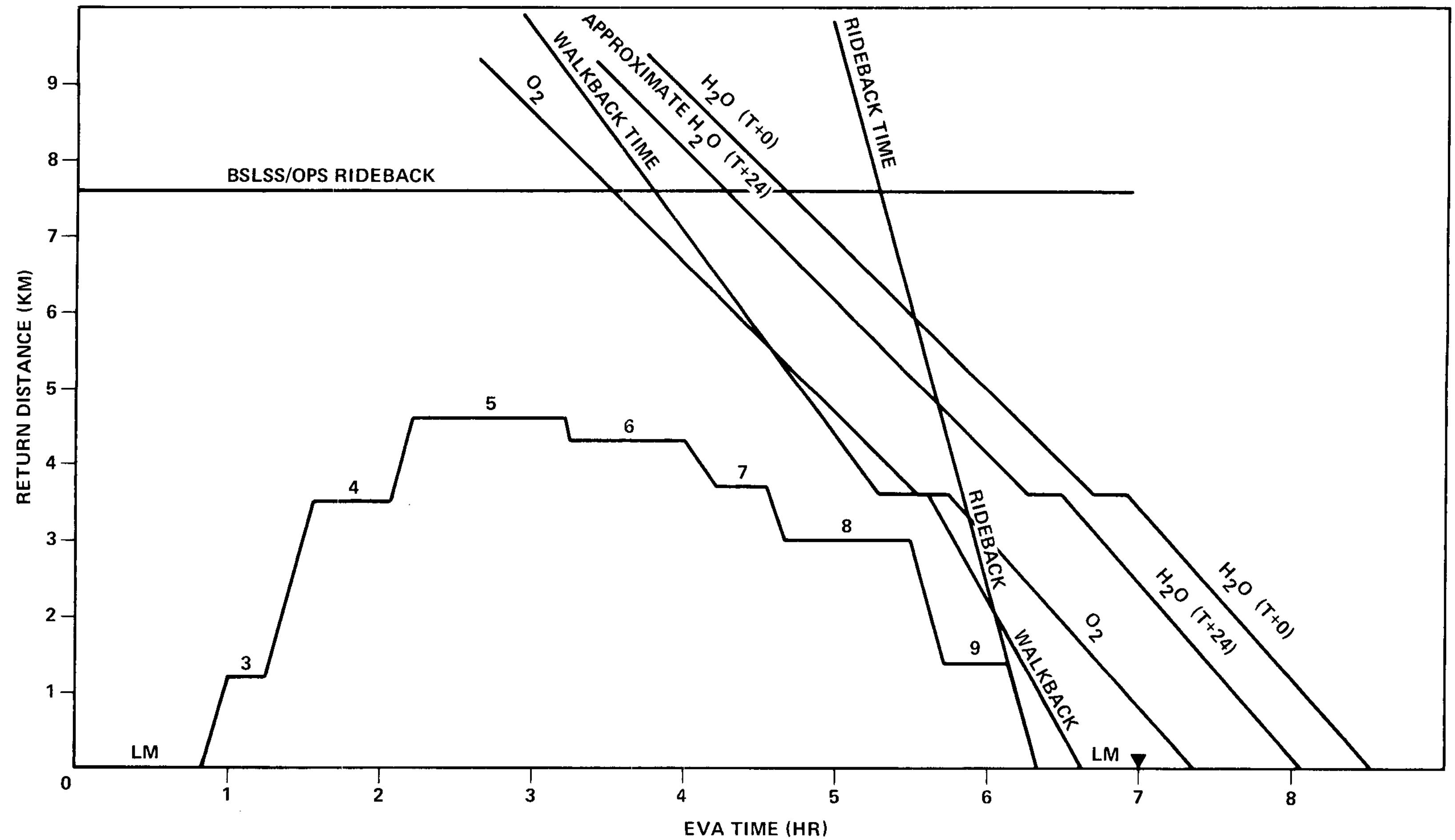


FIGURE 2 - APOLLO 16 LRV TRAVERSE CONSTRAINT ENVELOPE, EVA 2

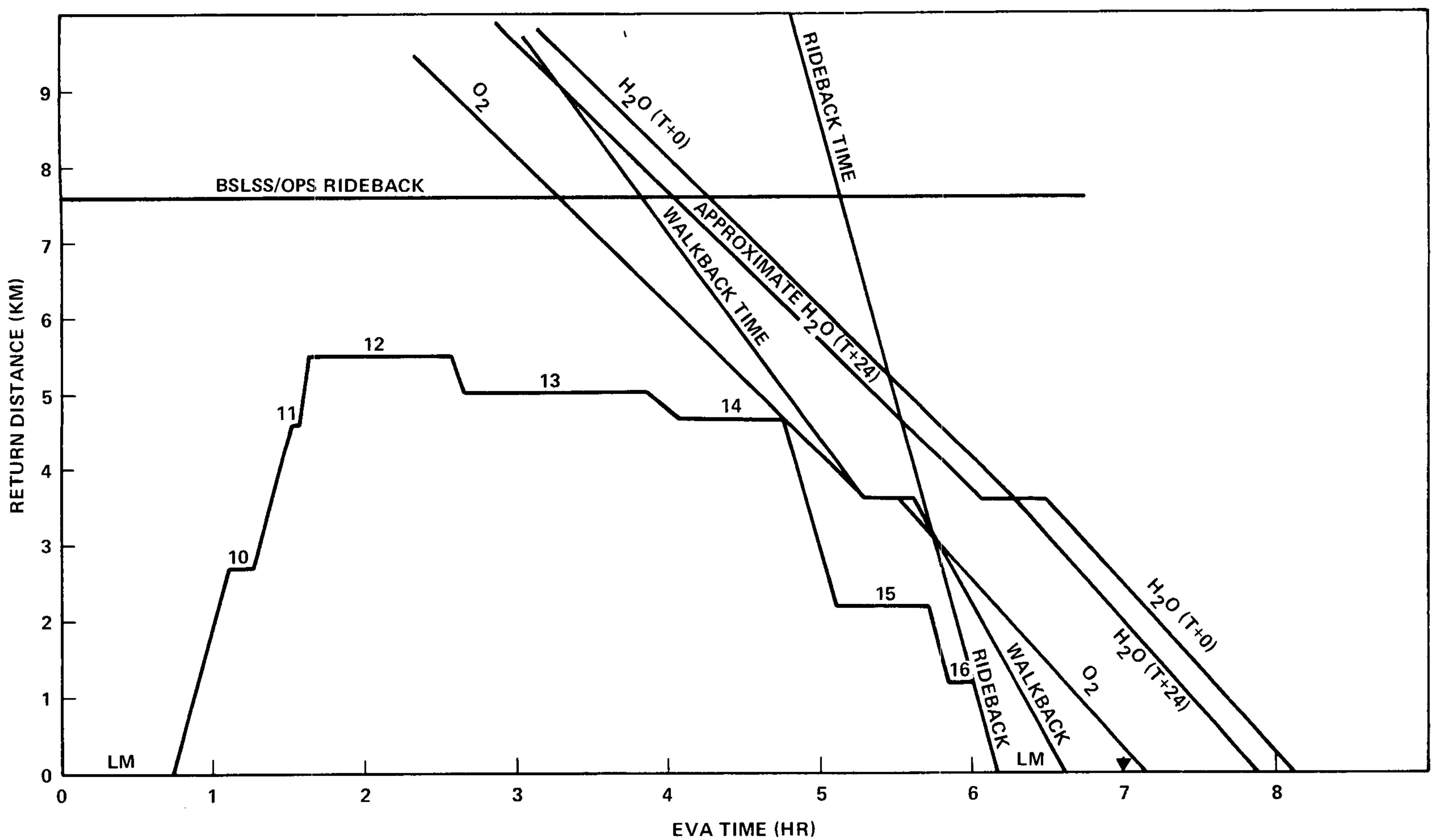


FIGURE 3 - APOLLO 16 LRV TRAVERSE CONSTRAINT ENVELOPE, EVA 3

23 min of activity is assumed to be the same as that for normal working. $O_2$ is consumed at a rate of

$$.0001627 \text{ (Metabolic Rate)} + O_2 \text{ Leak Rate}$$

in lb/hr. Therefore, for a traverse station a return distance D from the LM, a minimum quantity

$$Q = \frac{D}{R}(.0001627\ M + L) + \frac{23}{60}\dot{O}_2$$

of $O_2$ would be required for an emergency walkback, where

Q = total quantity of usable $O_2$ remaining (lb)
D = return distance to the LM (km)
R = emergency walkback rate (km/hr)
M = walkback metabolic rate (BTU/hr)
L = $O_2$ leak rate (lb/hr)
$\dot{O}_2$= actual $O_2$ usage rate for working (lb/hr).

The crew must leave a station with at least Q lb of usable PLSS $O_2$ remaining to protect the emergency walkback requirement.

The actual quantity of PLSS $O_2$ remaining is tracked by the TELMU team in Mission Control during each EVA. The data are plotted on charts such as that of Figure 4. After about 3 to 3.5 hr of EVA, the $O_2$ consumption rates are extrapolated forward to predict the maximum duration of the EVA as far as $O_2$ quantity is concerned. Using the predicted time of usable $O_2$ depletion and the actual quantity of usable $O_2$ remaining at any point in the EVA, the minimum quantity of $O_2$ required to provide for an emergency walkback can be calculated as a function of return distance to the LM. If t is the time in hr remaining to depletion of usable $O_2$, then $\dot{O}_2$ can be closely approximated by Q/t, and we have

$$Q = \frac{D}{R}(.0001627\ M + L) + \frac{Q}{t}\left(\frac{23}{60}\right) .$$

Rearrangement gives

$$Q = \frac{Dt}{R(t-\frac{23}{60})}(.0001627\ M + L\ ) .$$

Plots of Q versus t for constant D can then be drawn using

R = 3.6 km/hr, M = 1560 BTU/hr for D $\leq$ 3.6 km,
R = 2.7 km/hr, M = 1290 BTU/hr for D > 3.6 km, and
L = .0275 lb/hr.

The actual value of L for any EVA may differ from .0275 lb/hr, but pre-mission predictions range only from .02 to .035 lb/hr. Thus, the error in the calculation of Q using L = .0275 lb/hr is expected to be < 3%. Figure 5 shows Q versus t for D ranging from 0 to 7 km. Interpolation between curves of constant D is linear for constant t. Two curves are plotted for D = 3.6 km. One curve is associated with walkback times greater than 1 hr, and the other with times less than 1 hr. Q becomes very large as t approaches 23 min in order to protect the time allotted at the LRV and for ingress. Q was calculated in lb and was converted to psia using the ratio of 800 psia/lb, which corresponds to a PLSS $O_2$ bottle temperature of about 85°F.

For use during a mission, a transparency of Figure 5 can be laid over a plot like Figure 4 to provide a quick and easy determination of the departure time from a station required to preserve the emergency walkback capability. The origin of Figure 5 should be located at the point at which usable $O_2$ depletion is predicted, as shown in Figure 6. A station at a return distance D from the LM must be departed by the time the actual $O_2$ quantity falls below the boundary in the overlay. For example, if $O_2$ consumption on EVA 3 of Apollo 16 is as it was on EVA 1 of Apollo 15, Figure 6 shows that Station 14 (4.65 km from the LM) would have to be departed about 2 hr 15 min before the predicted time of usable $O_2$ depletion. Since usable $O_2$ depletion is predicted at 6 hr 33 min, Station 14 would have to be departed at 4 hr 18 min into the EVA, or 28 min before the planned time, in order to protect the PLSS walkback capability.

The maximum expected error in the required departure time as determined using the curves of Figure 5 is about (2 + 3t) min. Of this error, the 2 min is due to the maximum expected error introduced by approximating $\dot{O}_2$ by Q/t (corresponding to an error of 100 BTU/hr in the metabolic rate for working), and the 3t min is due to the maximum expected error in the assumed $O_2$ leak rate. The leak rate errors could be largely eliminated by constructing several families of boundary curves corresponding to a range of leak rates and using the set that matches the best estimate of the actual leak rate of the pacing crewman in any EVA. A somewhat more accurate value for $\dot{O}_2$ could also possibly be determined; however, the error associated with this value would not be much smaller than that involved in using Q/t.

Since several of the planned stations on the Apollo 16 traverses will likely be time limited by the $O_2$ walkback constraint, the TELMU team should be able to inform the Experiments Officer of the latest allowable departure time from such stops well enough in advance to allow adequate real-time traverse planning. The proposed chart should make this possible with little difficulty and reasonable accuracy. Similar boundary curves could be constructed for PLSS $H_2O$ walkback requirements; however, $H_2O$ is not expected to be constraining for a fully charged PLSS.

K. P. Klaasen

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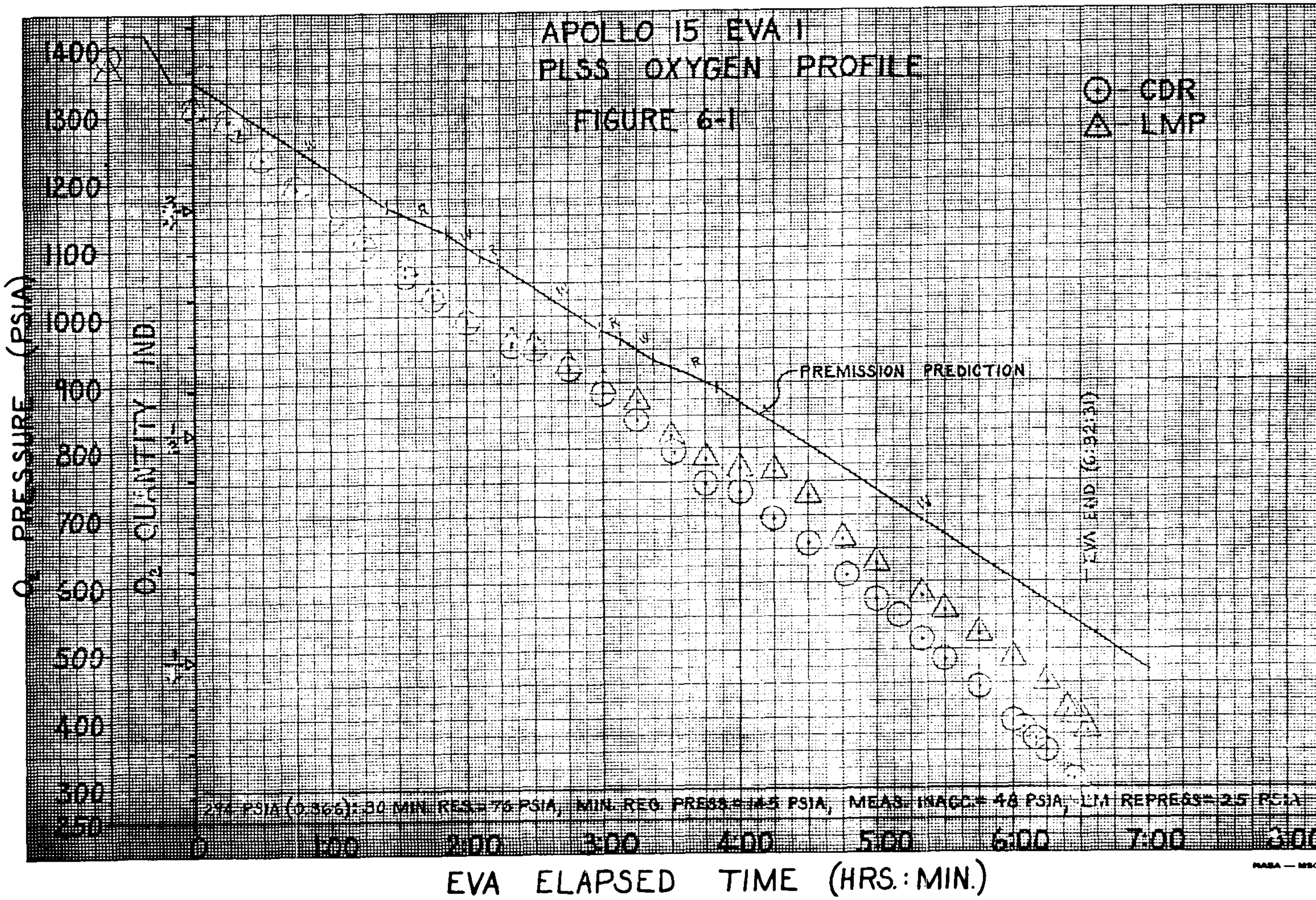


FIGURE 4 - REAL-TIME PLOT OF PLSS $O_2$ REMAINING VS EVA TIME

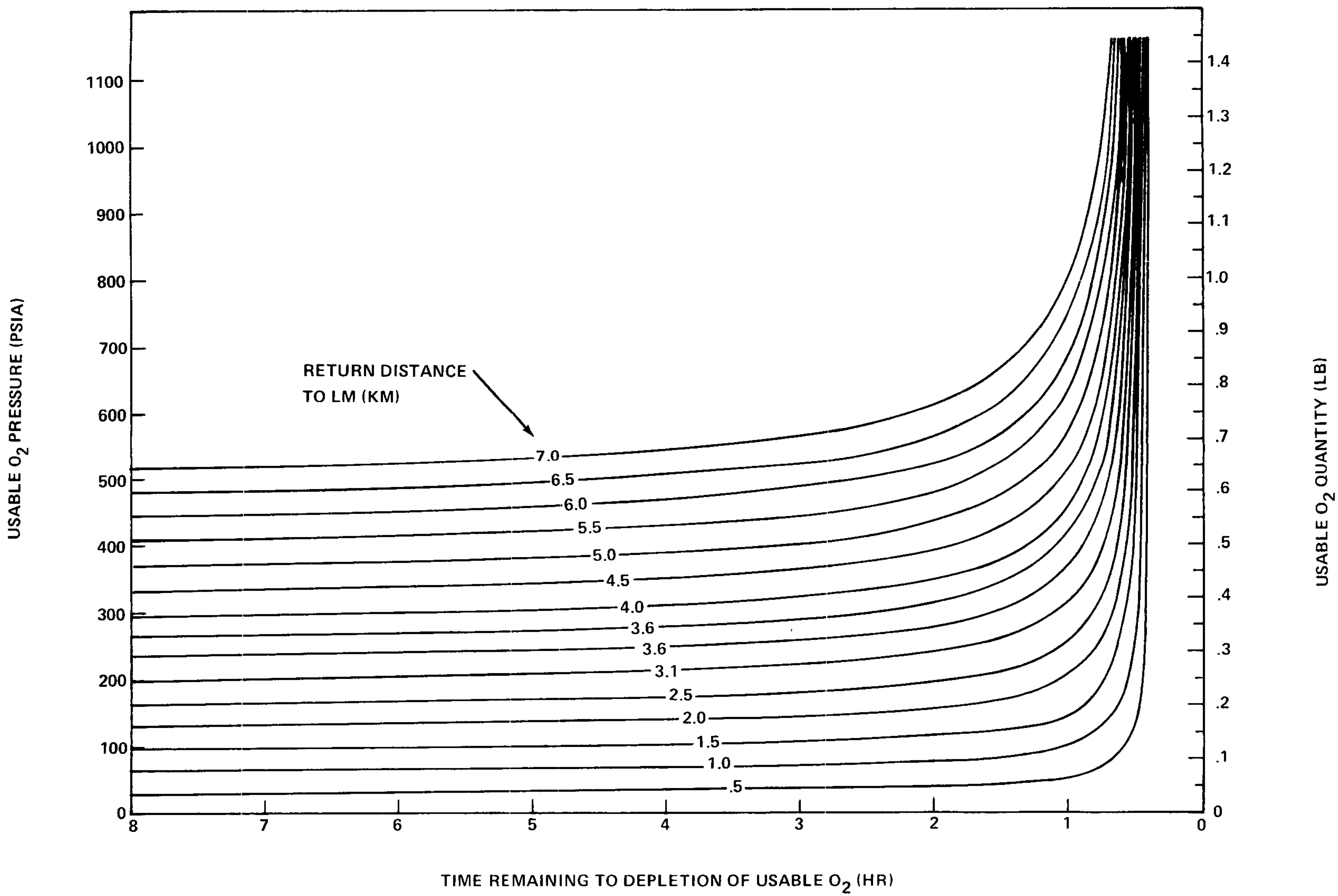


FIGURE 5 - REQUIRED QUANTITY OF USABLE $O_2$ VS PREDICTED TIME TO DEPLETION

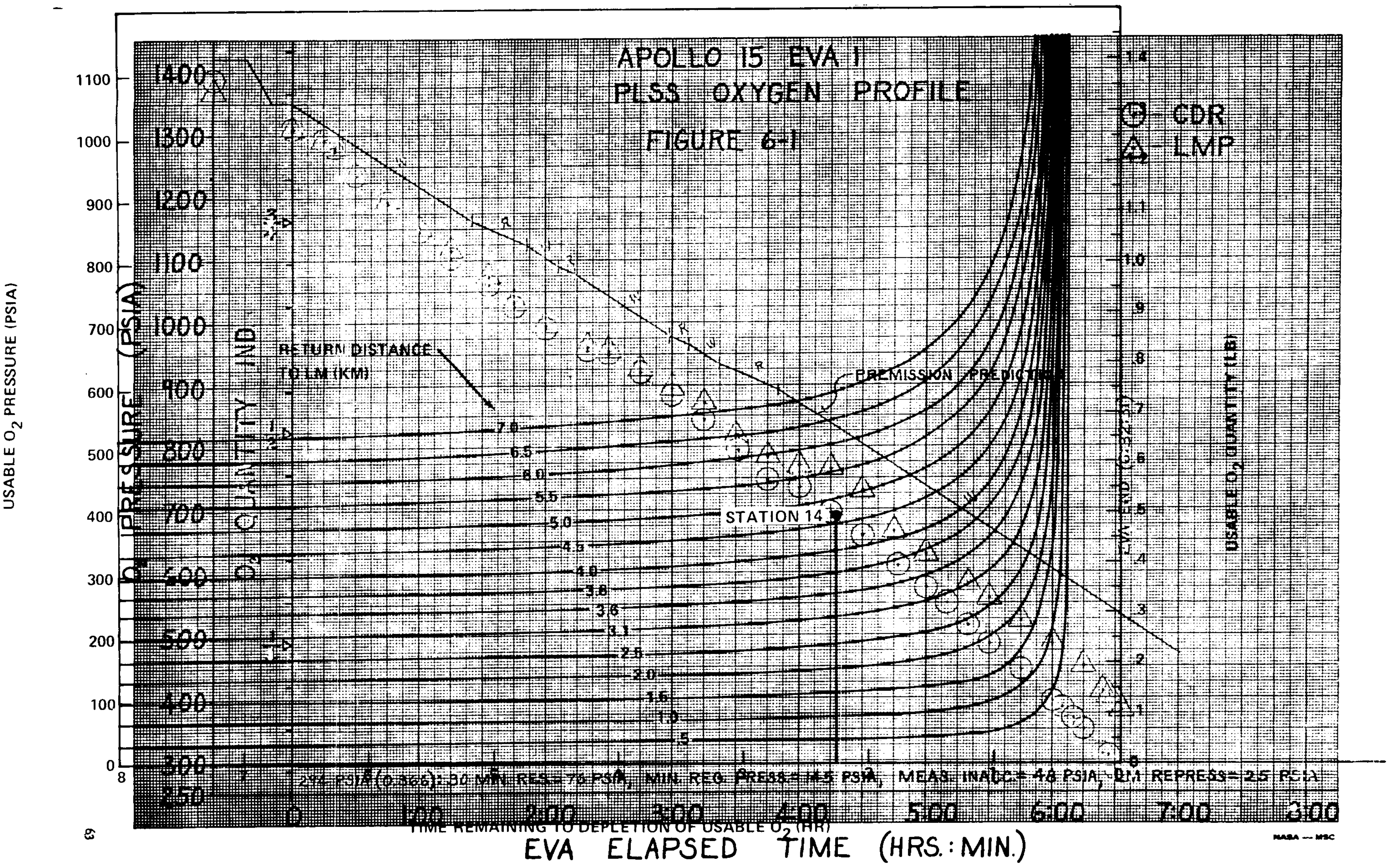


FIGURE 6 - $O_2$ WALKBACK BOUNDARIES OVERLAID ON $O_2$ QUANTITY PLOT

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